# TARDEC Forges Technological Advances in Fuel Cell Auxiliary Power Unit (APU) Development

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**A key challenge facing the U.S. Army today is the ability to provide reliable power for Soldiers and their tactical vehicles. Current military vehicle electrical sources are limited in supplying power for extended periods of time, thus limiting tactical tasks such as command and control, digital communication, silent watch and continuous power generation independent of the main engines.**

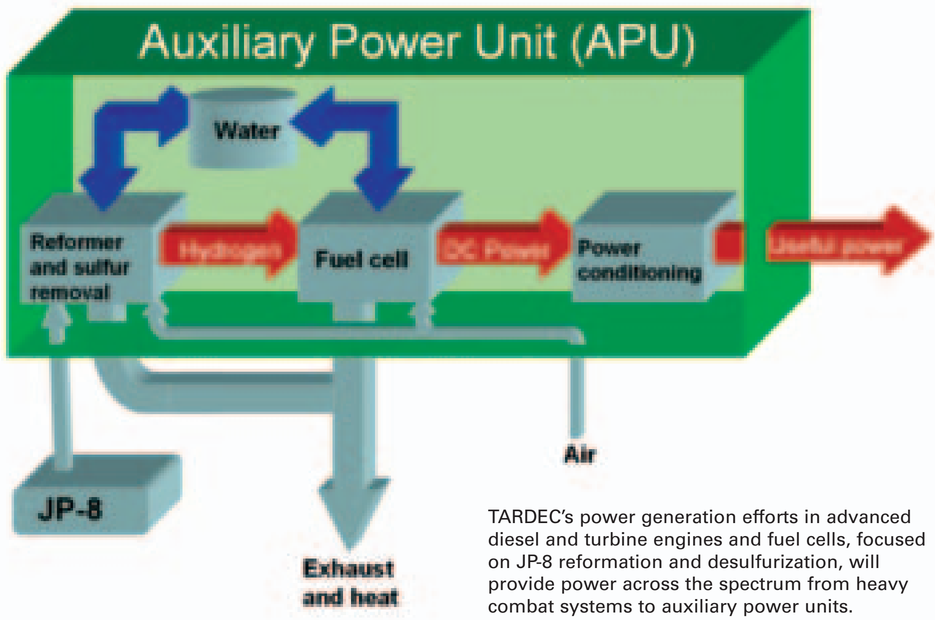
TARDEC is developing regenerative fuel cell auxiliary power. The program's second phase — begun in early 2005 — will integrate a regenerative fuel cell APU into a Stryker vehicle for demonstration in fall 2005. (Photo by TSGT Mike Buytas, 1st Combat Camera Squadron.)

Electrical power demands for military vehicles will exceed the current capabilities across all platforms because of new advances in technologies being spiraled into these systems. The U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) has developed a fuel cell program with the objective of enabling a 10-kilowatt (kW) fuel cell APU powered by logistic fuel as depicted in the figure on Page 62.

> NAC specializes in dual-use technologies — those that have both military and commercial applications.

## Risk Mitigation

For this program to succeed, TARDEC has worked closely with vehicle program managers (PMs) to solicit their specific needs and requirements. This collaboration has resulted in a clear definition of Current Force and future Unit of Action power requirements, form, fit and functionality. The program has been designed as a collaborative task among research and development (R&D) efforts and activities within government and industry, with a focus on desulphurization and hydrogen generation via JP-8 reforming. JP-8 is a kerosene-based fuel used in military jets, tanks and other fighting vehicles. The goal is to capture knowledge developed by these partners for




TARDEC's power generation efforts in advanced diesel and turbine engines and fuel cells, focused on JP-8 reformation and desulfurization, will provide power across the spectrum from heavy combat systems to auxiliary power units.

the purpose of risk mitigation and cost savings over time.

TARDEC is developing Memorandums of Agreement (MOAs) with many other DOD and government agencies to leverage their current efforts in fuel cell component development. Additionally, many National Automotive Center (NAC) programs will be enablers to this effort. These MOAs and Joint programs will be the risk mitigators for technology development. This will allow the TARDEC program to focus on fuel reformation and integration issues.

## History

Through January 2004, TARDEC's fuel cell program was centered at the NAC. The NAC specializes in dual-use technologies — those that have both military and commercial applications. The program can be characterized as being fuel-cell neutral and moving incrementally toward JP-8-fueled systems in both component development and system demonstrations.

A significant early demonstration was of the first liquid-fueled, fuel cell APU on a vehicle. This was a methanol-fueled, proton exchange membrane (PEM) APU on a Freightliner® long-haul tractor. The system was developed and built by Ballard Power Systems and was first demonstrated publicly in March 2003. Collaborative R&D continued with several component development programs that sustained the development of fuel reformers for more complex and "JP-8-like" fuels.

The next major demonstration was a synthetic-jet-fuel-powered PEM APU on a Bradley M2A3 during February 2005 at the Association of the United States Army (AUSA) Winter Symposium in Fort Lauderdale, FL. This system was designed and assembled through collaborative efforts between United Defense, Battelle and Pacific Northwest National Laboratory. The PEM APU is significant because it is the first complex hydrocarbon-fueled APU and it is the first one installed in a military combat vehicle.

TARDEC features a high-tech fuel and lubricant facility that researches properties and durability of a wide range of fuel, including environmentally friendly diesel and lubricants. (U.S. Army photo.)

In addition to reformer-based systems, TARDEC continues to develop regenerative fuel cell auxiliary power. In this type of system, an electrolyzer uses vehicle power to decompose water into hydrogen and oxygen. The hydrogen is stored and is later used in a fuel cell for silent watch or standby electrical power generation. TARDEC has teamed with Hydrogenics to develop this concept, which was first demonstrated as a proof of concept in January 2004. The program's second phase began in early 2005 to integrate a regenerative fuel cell APU into a Stryker vehicle for demonstration in fall 2005.

In January 2004, TARDEC formed an integrated process team (IPT) within the Mobility Division at TARDEC to more effectively leverage the diverse talents across the center. A critical initial IPT task was to develop a program plan to take the APU development program to its next major milestone — the demonstration of a JP-8-fueled brass board, with a follow-on effort to develop, integrate and validate a JP-8 fuel cell APU on board a tactical vehicle.

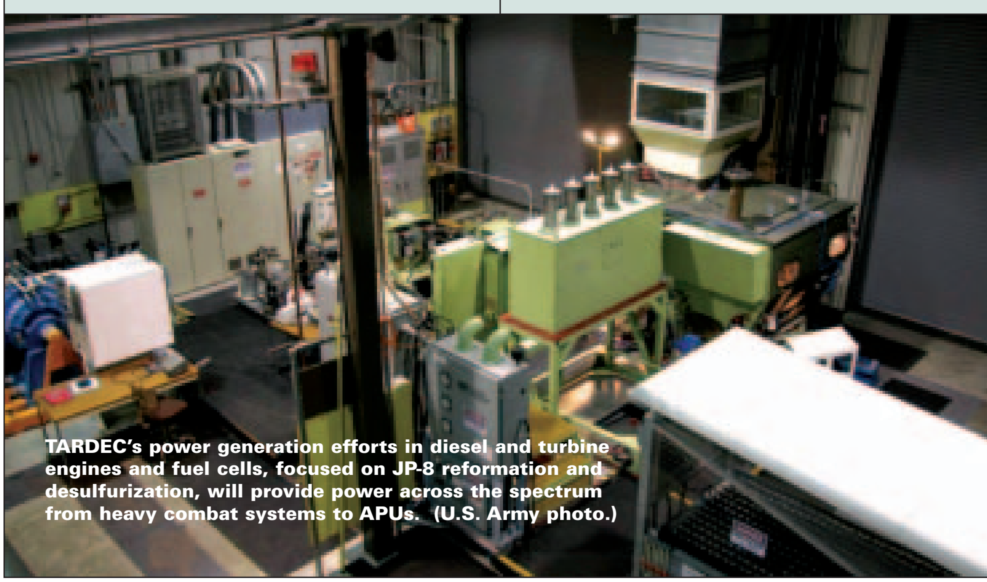
The current TARDEC JP-8 fuel cell APU effort will integrate the PM's needs and requirements, and aggregate these needs into a form, fit and functionality roadmap that will accelerate the technology readiness level of key technology platforms.

Today, a significant technical and logistical challenge is to produce hydrogen in the theater of operations to produce power via the fuel cell. Ongoing TARDEC R&D initiatives are progressing to leverage fuel cell development for military applications to augment current fuel sources for sustained tactical operations. (U.S. Army photo by SGT Arthur Hamilton, 55th Signal Co. (Combat Camera).)

The TARDEC program strategy for development and technology transition is a phased approach. For starters, the program is developed around a set of requirements for the Abrams, Bradley and Stryker vehicles. Secondly, the program's technology thrusts are being driven to meet these vehicles' operational requirements. By mid-FY06, there will be a determination if these two paths will intersect. The current program's scope is to develop a laboratory system to overcome the technical challenges of JP-8 reformation. If successful, the next step will integrate a complete fuel cell with JP-8 reformation into a vehicle and perform vehicle test evaluations.

## Potential Solution

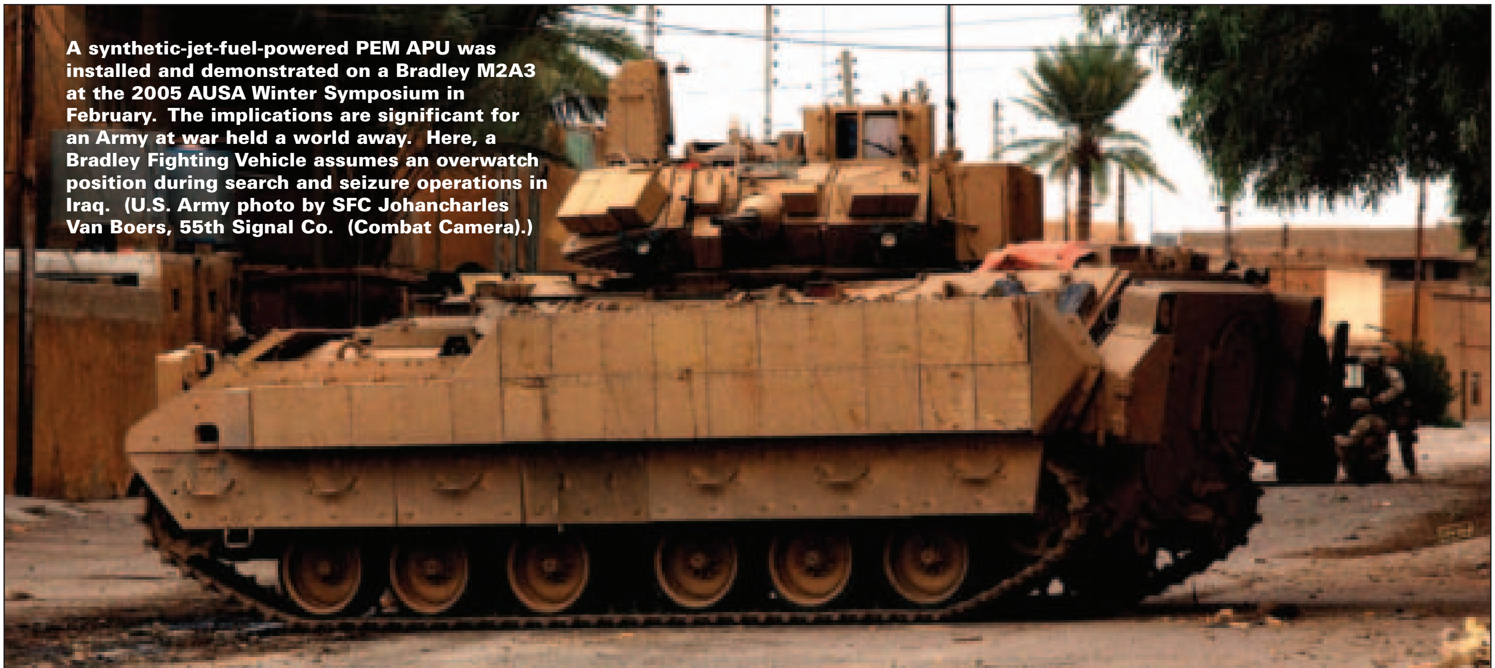
The most promising technology to address these power deficiencies is fuel cell technology. To better understand the technical challenges of this effort, one must understand the basics of how fuel cells work. A fuel cell is an electrochemical energy conversion device that converts hydrogen and oxygen from air into electricity with byproducts of water and heat. Fuel cells can separate the fuel from the energy conversion device, thus allowing continuous power generation, assuming that an endless supply of hydrogen and air is available. Oxygen from air is unlimited, but hydrogen, the other key ingredient, which is used in industrial applications, is not readily available for military applications. Consequently the technical and logistical challenge is to produce hydrogen in the theater of operations to produce power via the fuel cell.



TARDEC's power generation efforts in diesel and turbine engines and fuel cells, focused on JP-8 reformation and desulfurization, will provide power across the spectrum from heavy combat systems to APUs. (U.S. Army photo.)

## Fuel Cell Challenges

Over the last decade, significant R&D funding from the government and private sector has been directed toward the emerging fuel cell industry, significantly



A synthetic-jet-fuel-powered PEM APU was installed and demonstrated on a Bradley M2A3 at the 2005 AUSA Winter Symposium in February. The implications are significant for an Army at war held a world away. Here, a Bradley Fighting Vehicle assumes an overwatch position during search and seizure operations in Iraq. (U.S. Army photo by SFC Johancharles Van Boers, 55th Signal Co. (Combat Camera).)

accelerating technology readiness, reliability and durability. Although no substantial commercial applications have begun, costs of fuel cell components have been decreasing and continuous engineering improvements have drastically advanced fuel cell stack durability and balance of plant (BOP). The BOP is the equipment that surrounds the fuel cell stack — the blowers, humidifiers, valves and controllers, as well as software and electronics that manage the operation of the fuel cell power module. This effort needs to be leveraged on fuel cell development for military applications.

Another major challenge is leveraging developments from the private and public sectors to focus on power requirements for military applications. The key deliverables are technology readiness, affordability, durability and reliability. Furthermore, fuel cell system designs must be focused on military-specific requirements such as performance, ruggedization, reliability and durability.

## Sulfur Removal and Hydrogen Reformation

Hydrogen is the primary fuel for fuel cells and there are no current plans to add hydrogen to the strategic and tactical operations logistics burden. The challenge is to produce hydrogen on board from the existing JP-8 fuel. Although research activities have advanced over the past several years in reforming methanol, gasoline, diesel and synthetic diesel to hydrogen suitable for fuel cells, significant technical challenges still exist in reforming JP-8 to be fuel cell compatible. JP-8 is produced in refineries worldwide. However, the type and origin of the base crude and refining processes is critical because the fuel produced can contain a wide variance — 30 to 5,000 ppm — of sulfur. For fuel cells, sulfur and carbon monoxide tolerance, fuel vaporization and processes to reduce carbon coking are not widely understood. Although there is significant research activity and 6.1 funding to investigate the sulfur removal and subsequent reforming of JP-8, these technologies are in the early stages of development and assessment. It is imperative that a broad assessment of the R&D activities be funded and leveraged to assure that the technology develops into a realistic solution for our Soldiers.

Modularity and optimization of components, packaging, synergy and scalability are all essential for the complete fuel system integration as an APU.

Using JP-8 fuel stresses the designs for the conventional fuel processors used to convert the fuel into hydrogen-rich gas. The requirements for an APU also challenge the scalability of conventional fuel processors. JP-8 reformation is the most difficult challenge to overcome to make this technology successful, and this is the core focus of TARDEC's ongoing efforts.

## System Integration

Another significant technical challenge for TARDEC is to ensure that key integration issues for the complete system meet the program objectives. Modularity and optimization of components, packaging, synergy and scalability are all essential for the complete fuel system integration as an APU.

The integration of a fuel cell stack, a fuel processor, sulfur removal process and gas purification process into a functional APU will require close collaboration with the respective PMs to ensure the necessary BOP meets and exceeds the respective overall system requirements regarding form, fit and functionality. Thermal management, and the corresponding issues of thermal integration and management, must be considered because they become increasingly complex as the system size is reduced.

This strategic fuel cell program must address and then correct the critical power deficiencies that exist today in tactical vehicles. It is imperative that the following key metrics be established and measured:

- Risk mitigation through effective and efficient collaboration and knowledge transfer with government and industry participants.
- JP-8 desulfurization and reformation to yield hydrogen acceptable for fuel cell APU.
- Fuel cell design, development and validation that meet or exceed power requirements and are complementary to desulfurization and reformation activities.
- System integration activities that optimize the laboratory system to meet test and validation goals and demonstrate a technology path that complements follow-on activities.
- Roadmap for cost reductions, reliability, durability and ruggedness.
- Modularity and scalability for adoption across vehicle platforms.

TARDEC is committed to bridging today's power gap for vehicular and mission needs through the development and assessment of a JP-8 fuel cell APU. This is a multiyear development program with a strategic roadmap that delivers a complete functional system based on PM needs and actual vehicle requirements. The opportunity for collaboration with other services, agencies and industry is extremely valuable to ensure successful program execution and system integration. Likewise, TARDEC envisions that these "front-end" project activities will help reduce project costs, accelerate production timelines and reduce program risk over time.

The PEM APU program's second phase, which began in early 2005, will integrate a regenerative fuel cell APU into a Stryker vehicle, such as this one on patrol in Iraq, by fall 2005. (U.S. Army photo.)

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